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March 2013

CIRRELT-2013-14

Document de travail également publié par la Faculté des sciences de l'administration de l'Université Laval, sous le numéro FSA-2013-002.

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Functional Design of Physical Internet Facilities: A Road-Rail Hub†

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Abstract. As part of the 2010 IMHRC, Montreuil, Meller and Ballot enumerated the type of facilities that would be necessary to operate a Physical Internet (PI, π), which they termed, "π-nodes". This paper is part of a three-paper series for the 2012 IMHRC where the authors provide functional designs of three PI facilities. This paper covers a PI road-rail hub. The purpose of a PI road-rail node is to enable the transfer of PI containers from their inbound to outbound destinations. Therefore, a road-rail π-hub provides a mechanism to transfer π-containers from a train to another one or a truck or from a truck to a train. The objective of the paper is to provide a design that is feasible to meet the objectives of this type of facility, identify ways to measure the performance of the design, and to identify research models that would assist in the design of such facilities. The functional design is presented in sufficient detail as to provide an engineer a proof of concept.

Keywords. Physical Internet, interconnected logistics, multimodal transportation, road-rail hub, facilities design, sustainable design, mobility web, functional design, logistics facilities, transshipment, crossdocking.

Acknowledgements. This work was supported in part by the PREDIT research program in France, the Canada Research Chair in Enterprise Engineering and the Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant program in Canada. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the above programs. The authors also thank research students Marie-Anne Côté, Driss Hakimi, Christelle Montreuil and Zachary Montreuil for their help with hub sketching and figure production, and Professor Russell D. Meller for setting up the model of work presentation used in the three-paper series.

† The content of this document is to be published as a chapter of the book "Progress in Material Handling Research 2012" edited by B. Montreuil, A. Carrano, M.M.R. de Kostner, K.R. Gue, M. Ogle, J. Smith, MHIA, Charlotte, NC, U.S.A.

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1 Background

The Physical Internet (PI, π) was presented by Montreuil [11] as a response to what he termed the *Global Logistics Sustainability Grand Challenge*. This grand challenge covered three aspects of sustainability: economic, environmental and social, using symptoms from today's logistics system as evidence of the unsustainability of our present system. The PI is defined as an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols. The PI enables an efficient and sustainable logistics web that is both adaptable and resilient.

The term, Physical Internet, employs a metaphor taken from the Digital Internet, which is based on routers, all transmitting standard packets of data under the TCP-IP protocol. A core enabling technology to make the PI a reality exploit is the encapsulation of goods in modular, re-usable and smart containers. This will make it possible for any company to handle any company's products because they will not be handling *products* per se. Instead they will be handling standardized modular containers, just as the Digital Internet transmits data packets rather than information/files.

Another enabling technology of the PI is an open standard set of collaborative and routing protocols. Modularized containers are much easier to route through transport networks as individual "black-box" loads instead of heterogeneous loads of different-sized cases and pallets. But the efficient routing of modular containers over a collaborative network can only be realized if there is a standard set of routing and digital protocols, as well as business and legal conventions that apply across a community of users.

And of course, handling and digital interfaces are needed to ensure reliability, security, and transparency as well as that the quality of the product being handled is not compromised through its movements. These interfaces cannot be proscribed, but the functional requirements need to be so that innovative interfaces may be developed.

A simplified mental image of the PI business model is to imagine an eBay-like freight transportation "auction" that handles "black-box" modular containers through an open and shared network with a vast community of users that utilize supplier ratings to drive logistics performance. This creates a multi-scale process where at the lowest level we have individual containers and at the highest level we have an international network of transportation, storage and services resources.

The PI was discussed extensively as part of the 2010 IMHRC held in Milwaukee. After an introduction of the PI by Montreuil [10], roundtable discussions focused on further defining the PI. As part of the poster session at the 2010 IMHRC, the first paper on PI facilities was presented and later published in *Progress in Material Handling Research: 2010* [12]. This paper proposed a set of facility types that would be necessary to operate a PI. Such facilities were termed π-nodes. The complete set of π-nodes included: transit nodes, switches and bridges, hubs, sorters, composers, stores and gateways. The π-nodes vary in terms of purpose, scope and scale, as well as in terms of capabilities and capacities, yet they all have in common that they are explicitly designed

to handle π-containers with respect to the physical, operational and informational protocols of the PI.

Although we believe this is a compelling vision for the future of logistics, there are a number of reasons why we cannot deploy the PI today. First, there is no agreed-upon standard for various container sizes outside of the international shipping containers. This, and the lack of standard contracts and other operational issues, mean that collaborative distribution is difficult to initiate and maintain. And expanding collaborative distribution is limited by the fact that there is not a centralized exchange for freight based on a standardized specification of a load, with the lack of standardized specification of a load due to the lack of standard containers. Other circular arguments on the use of the rail system, due to the currently time-inefficient design of switch yards, the lack of innovation due to the difficulty in justifying innovation when what is handled is so diverse, and the inability to construct facilities that will act as the backbone of the PI until there are users of the PI, all mean that there are a number of research questions and business issues that must be addressed before the PI is to become a reality.

Current research on the PI is focused on a few of the many questions related to it. The three questions that have been investigated with completed or on-going projects are: 1) the design of PI facilities; 2) the impact of modular containers on shipped volume; and 3) the impact of open distribution webs.

Parallel to the 2010 IMHRC, Meller and Montreuil [8] research contract from MHIA to investigate the impact of PI on facility and material handling system design, Ballot, Glardon and Montreuil [1] were awarded a research contract from PREDIT in France to investigate the conceptual design of a bimodal road-rail π-hub. This second chapter in this series is the result this project. Figure 1 illustrates the role of the hub to interconnect flows to and from various origins and destinations to develop the backbone of an interconnected logistics network. This project also studied how PI can help address multimodal issues [3]. The third chapter in the series [13] presents a conceptual design of a distribution π-hub resulting from the MHIA project by Meller and Montreuil [8].

Figure 1: Example of how hubs can structure logistics networks vs. the actual situation

As one of the key characteristics of the PI is encapsulation of goods in modular containers, Meller and Ellis [5, 6] are investigating the impact of these standardized modular containers on the amount of shipped volume. Although one of the concerns for moving to a PI was that limiting the choices on container sizes would increase the amount of shipped volume, as has been shown in [7], this is not likely an impediment to the PI, especially if the products are currently shipped on pallets. That is, although the shipped volume may increase as much as 10% at the case level, the shipped volume decreases by 10% at the pallet level if some flexibility is permitted in the number of items shipped per case.

The potential of the PI to address the Grand Challenge relates to how much waste can be removed from the system by sharing resources. Both the Meller and Ellis [6] and Ballot, Montreuil and Glardon [2] projects examine this question. Although their assumptions, data and methodology differ, both studies indicate that the miles driven and the CO_2 emissions can be cut by 25-50% with even a partial adoption of the PI.

In the next section we provide the motivation and the mission for the road-rail PI hub in more detail, which includes the motivation for not using classical railcar marshaling yards, as well as the design goals and key performance indicators (KPIs) that could be used to measure a design realization's performance. We also "close the loop" and discuss how such a facility would help achieve the Global Logistics Sustainability Grand Challenge. Then in Section 3 we provide a conceptual design of the facility as well as our design process. The objective of this section of the paper is to provide a functional design and a realization of the design that is feasible to meet the objectives of this type of facility. We incorporate sufficient detail so as to provide an engineer a proof of concept. We also provide estimated values for the KPIs identified in Section 2. In Section 4, we conclude the paper with our thoughts on future research that would be valuable in assisting with the design of such facilities.

2 Motivation and mission of a PI Road-Rail Hub

One could wonder why we want to create a specific road-rail hub with the mission of transferring containers from truck to train and vice-versa and from a train to another train. In fact two types of facilities already exist. First, there are multimodal terminals where a trailer or a maritime container is loaded on a train. Second, there are the classic marshaling yards where inbound trains are dismantled, railcars sorted one by one and outbound trains formed. These two types of facilities present significant drawbacks whilst the train represents a major opportunity to reduce the environmental footprint of freight transportation: congestions, emissions and use of renewable energy. Thus the problem is to design a new type of road-rail hub that could overcome current drawbacks and cope with trains' constraints.

On one hand, if we look at the multimodal terminals, they usually serve only a line, with very few stops. It implies for the shipper to manage a complex transportation scheme with pre and post dispatches with other transportation means. On top of that, if a

trailer is loaded on the train, some gage issues may arise or if a maritime container is used, mismatching sizes with the trailer jeopardizes the pre and post transportation efficiency. At the end this solution currently remains marginal in the inland transportation landscape despite several attempts to extend the service.

On the other hand, the traditional freight train operations offer two services. The first service, full train operation, implies that a shipper is able to fill around 30 railcars to a single destination. This service deals only with bulk shipments of oil, coil, etc. No manufacturer is able to ship such a volume to a single destination. The second one offers railcar service. From a theoretical point of view, this service could compete with full truckload (FTL) service. However, the transit of a railcar through a marshaling yard requires a very long and often unpredictable lead-time. Compared with FTL, the railcar service offers longer lead-times, unreliable time of arrival and a limited number of destinations. So here again pre and post dispatches with other transportation means are required.

All in all, freight trains, the most environment friendly mode, lose their dominant position in freight transportation in most of the developed countries, bulk excepted. Therefore there is a huge stake to find an organization that overcomes the current downfall.

The aim of a road-rail π-hub is to efficiently and sustainably transfer containers from trains from one line to trains from another line or from and to trucks. The basic idea of the road-rail π-hub is: 1) to never dismantle trains to avoid very strict safety constraints; 2) to enable a real network with many destinations available with short lead-times; 3) to smoothly interconnect with truck services.

To reach these goals, the mission of a road-rail π-hub is: 1) to receive trucks and handle their inbound π-containers so they can be loaded in time in their assigned train and railcar so as to move them to their next rail-based π-node; 2) to receive trains and handle their inbound π-containers so they can be loaded as pertinent either on a truck called to pick them up or on a subsequent train so as to move them to their next π-node or their final destination; 3) to handle and sort π-containers in connection with either a truck or another train. These missions are illustrated in Figure 2 by the three columns and their links.

Such missions assume that some basic information is part of the PI operating protocol. First, all trailers will depart from origin locations with the requirement to be delivered at a destination location within a delivery time window. The pickup at the origin location may or may not be part of the PI, but at some π-hub, the load enters the PI and likewise on the delivery side to the destination locations. In this particular hub and because train services are not flexible, they set the pace for all operations. If the hub is not able to cope with the forecasted volumes, it is also the role of the PI protocols to switch extra volumes to road transit centers or the opposite, see [1] for more details on this.

The last task performed by the road-rail π-hub is to sort π-containers arrived with a train service and connecting with another train. This part of the π-hub takes the place of

the marshaling yards but handling π-containers instead of railcars, thus limiting the safety issues related to dismantling and composing trains. The aim of the road-rail hub is really to upgrade the performance of freight train networks to a next level.

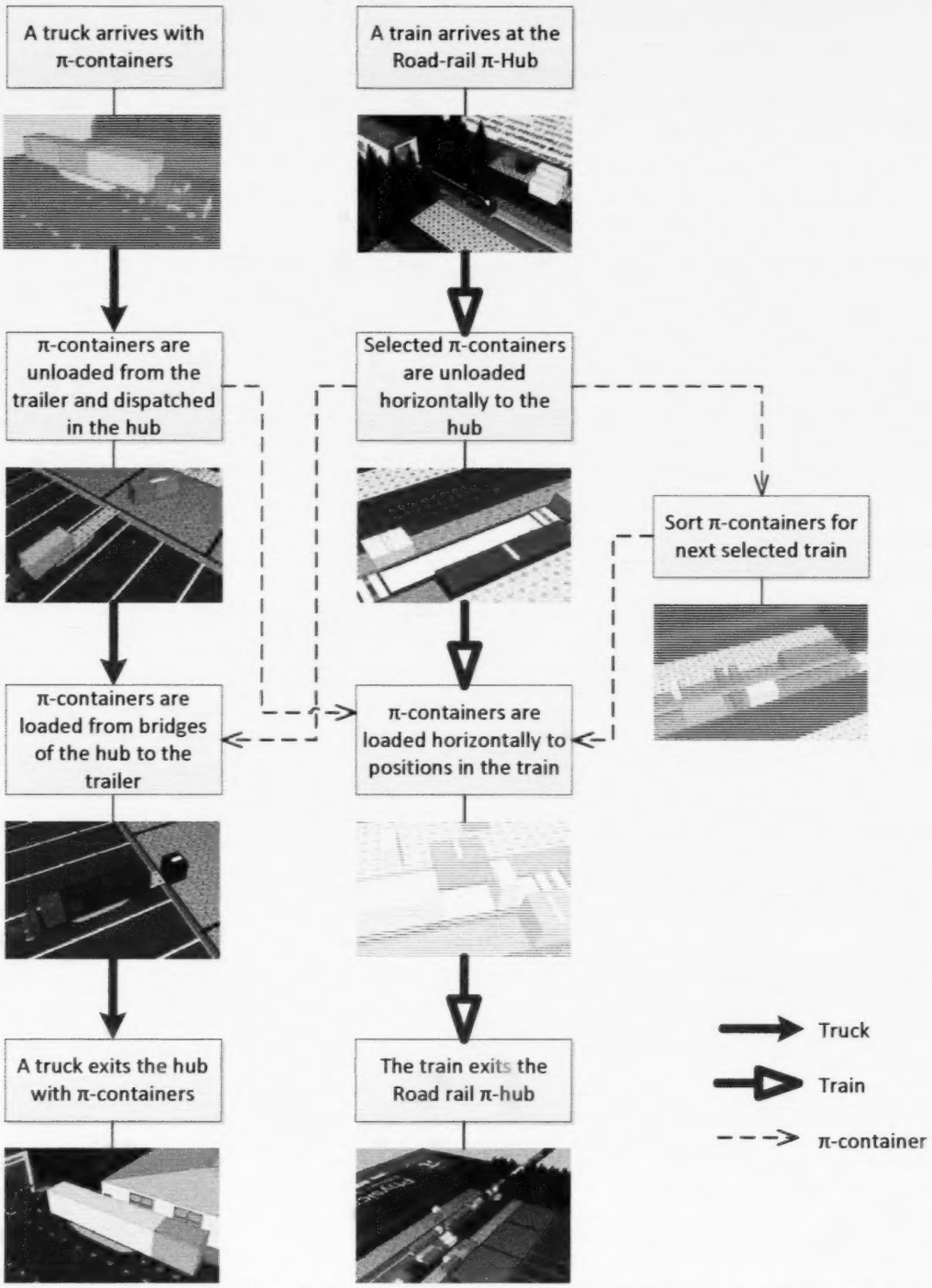
A truck arrives with π-containers
A train arrives at the Road-rail π-Hub
π-containers are unloaded from the trailer and dispatched in the hub
Selected π-containers are unloaded horizontally to the hub
Sort π-containers for next selected train
π-containers are loaded from bridges of the hub to the trailer
π-containers are loaded horizontally to positions in the train
A truck exits the hub with π-containers
The train exits the Road rail π-hub
Truck
Train
π-container

Figure 2: Overview of the flow of trucks, trains and π-containers in the road-rail π-hub

2.1 Design Goals

There are three processes in the road-rail π-hub described above. The central one sets the pace of road-rail π-hub. This rail process is subject to some degree of uncertainly, such as delays, though it is expected to be limited (thanks to regular services). The main source of variation for the π-hub will be the number of π-containers to unload and load and their type from and to each train. The pace of truck and sorting operations will have to cope with trains' operations variations. On the truck side, some uncertainty is also expected. Thus, it is possible that the containers, the trailer, or both the trailer and driver will need to wait at the facility. The design of the road-rail π-hub, therefore, needs to accommodate some dimensioning issues and such queuing time in accordance with the sustainability principles of the PI. This paper deals with the dimensioning issues (train's handling time) while the queuing aspects will be explored in future work.

2.2 KPIs of Design

There are two sets of key performance indicators (KPIs) that we are interested. The first set of KPIs is from the perspective of "customers" of the road-rail π-hub. The second set is from the perspective of the operator of the road-rail π-hub. We here detail the two sets of KPIs below and then revisit this with our conceptual design at the end of Section 3.

2.2.1 From the Customer's Perspective

In simple terms, there are three customer perspectives to consider at a transit center. The first is the transportation service provider (represented by the truck/driver) the second is the train operator and the third is the shipper (represented by the π-container).

For the truck side of the hub, please refer the π-transit center paper of this series [9]. Traffic wise, we just mention the number of trucks resulting from trains operations and we focus on the train side of the operations.

For the train side, it is important to know what is the time spent in the road-rail π-hub, which is the sum of the time spent waiting at the gate, if any, being processed in the hub to unload and load π-containers and then waiting to join the rail network. We can combine all of these times into the "processing time" (unloading and loading of π-containers) from a hub perspective and the "stop time" more related to the rail operator and rail network operations. Of the two, the "processing time" is variable more related to the hub so we will present a model related to determining its value.

Thus, although there are many other KPIs of interest to the customer, the main six are:

1. Processing Time (Trains)
2. Number of trucks per hour (Trucks)
3. Empty places on transportation means (Trains & trucks)*
4. Average connections offered (Trains)

5. Maximum container's transit time (Trains to trains, trains to trucks & trucks to trains)
6. Average Percentage Departing in Preferred Direction (Trucks)*

The * refers to KPI only available after a dynamic simulation coupling several queues. They will not be determined here.

2.2.2 From the Operator's Perspective

For the operator of the road-rail π-hub, there is the typical tradeoff between capacity and costs. If the operator provides more containers handling bays, for example, then the average processing time and stop train will decrease, but the costs will increase due to the need for more land and handling robots. So, for now, we concentrate on KPIs related to the capacity of the road-rail π-hub:

1. Area of road-rail π-hub,
2. Number of railcars processed in parallel per stop
3. Number of π-containers processed in parallel per railcar
4. Number of load and unload bridges for trucks (In and Out of the π-hub)
5. Number of rows to store and sort π-containers before loading to trains (from trucks and from trains)
6. Number of rows to store and sort π-containers after unloading from trains (to trucks and to connecting trains)
7. Number of Gates (In)
8. Number of Gates (Out)
9. Number of Parking Bays in the buffer (Trucks/Trailers)
10. Average Percentage Trucks/Trailers Declined Entrance (due to space issues in the π-hub)*

But of course more KPIs are related to the operations of the road-rail π-hub:

1. Number of π-containers handled per period
2. Number of positions used in the π-hub per sector (saturation)*
3. Number of positions used in the buffer (saturation)*

2.3 Contribution Towards Economic, Environmental and Social Sustainability

In this section we summarize how our conceptual design of a road-rail π-hub contributes to economic, environmental and social sustainability. In fact, with another project we simulated a Physical Internet network of the food supply chain in France [13]. The first results from the simulation model do not deliver the complete picture of the contribution due to several limits (limited amount of flows, one sector, few warehouses and DC that add constraints) but it sets a first level of stakes that could be improved in the future when more interconnections will bring more π-containers.

From an economic point of view, the various scenarios tested performed better with improvement up to 25% compare to the reference scenario of actual operations. Of course the cost reduction depends on routing preferences (cost, time or environmental footprint minimization) and cost assumptions for the π-hubs. The hypothesis made is based on a road-rail container terminal already operated in France as a reasonable starting point. The comparison also includes container rental cost based on maritime container tariff. This economic result comes from several physical indicators that are detailed in the next two paragraphs concerning environmental and social impacts.

From an environmental point of view, several indicators were defined. Ton.km, modal split, fill rate and CO_2 are the most important ones. Ton.km varies among scenarios according to the degree of Physical Internet deployment. The more it is deployed the better is the result. The results show already that -10% of t.km is possible. For the fill rate expressed in weight, the actual number is 59%, while the Physical Internet reaches between 70% and 75.5% with limited flows. The modal split with a share of 2% raises to 56% for trains and here again more volume will increase that number. But the most impressive result comes from the CO_2 emissions with a cut down by 58%. The road-rail π-hub is a central component to reach these results as it enables efficient bimodal train operations.

From a social point of view, several indicators were defined: number of nights spent on the "road", number of trucks km removed, number of driver's job suppressed, and number of jobs created in the road-rail π-hub and within rail operators are the most important ones. According to the same study mentioned earlier, we measured 98% reduction of nights spent on the "road", a reduction of distance travelled by trucks of 61%, with 7% of the traveled reference distance now realized on railroads, thanks to the size of trains. In terms of truck driver jobs, it indicates a decrease from 1500 jobs needed to 600 and a creation of 75 train driver jobs. Of course this will not happen in a day, yet it shows the magnitude of the potential change.

Combined, the above will lead to fewer miles driven on the road and to fewer truck trips, which has significant positive economic and environmental impacts. Also, the networks themselves will lead to less congestion and to a higher quality of life for employees. The road-rail π-hub appears to be crucial enabler towards a more sustainable logistics.

3 Conceptual Design of Facility

The purpose of this section is to present a feasible conceptual design of a road-rail π-hub. We are purposely **not** attempting to present an optimal design but rather exploring its feasibility. Our hope is that our design provides an example of what must be provided in terms of specifying a design and that others will follow as they determine better designs of a road-rail π-hub.

3.1 Components of Facility's Design

In presenting our conceptual design of the facility, we will use many figures. And each figure will have up to five different types of flows represented on it. A color-coding is used, as illustrated in Figure 3.

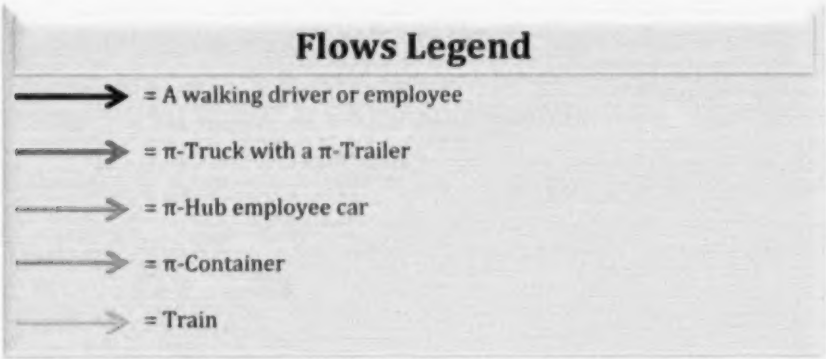

Figure 3: Legend of Flows in a Road-Rail π-Hub.

Note that at a high level, the road-rail π-hub facilitates the flow of π-containers from the road on trucks, facilitates their switch to trains, or vice-versa, and also facilitates the flow of π-containers from a train service to another one. Thus, Figure 4 represents the location of a road-rail π-hub relative to its connected road and the railroad infrastructures that support the services.

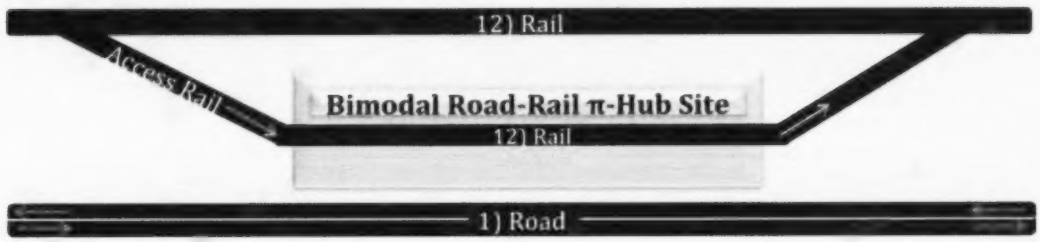

Figure 4: Illustration of road and railroad connection by a Road-Rail PI hub.

To facilitate the mission of the π-hub, the possible components we consider in a design are, as follows:

- The road-rail π-hub is positioned on the side of a railroad;
- The train and its railcars are never detached to avoid any safety issues and further inspection;
- The set of π-containers the hub deals with contains only one section about 2.4m per 2.4m (roughly the section of a maritime container) but with various lengths

from 1.2. to 12m. The potential set of lengths used in this paper is S={1.2, 2.4, 3.6, 4.8, 6, 12 meters};

- The train is processed within the hub in two sections of equal size by blocks of n railcars;
- The process of the train is based on a takt-time (e.g. 1 minute), valid for each handling operation (load a container or unload a container);
- Sorters are used to sort the containers between the two connecting services (road to train, train to road, or train to train). The sorters also functionnally provide a short term buffer;
- Bridges to rotate the container in the correction orientation to be looaded on a train or a truck.

Note that we focus here on the rail focused part of the hub itself as other components are further discussed in the other two papers of the series [9,12]**.**

3.2 Illustrating the Functional Design of Facility

In Figure 5 we present the flow diagram of our functional design of a road-rail π-hub that combines the facility components referred to earlier. We also illustrate the major flows with the legend provided earlier in Figure 3.

Note that, in general, the goal of the truck-trailer pair upon entering through the π-InGate is to make its way to the π-Hub itself. However, if there is no bridge currently available in the π-Hub, we must provide a buffer for the pair to wait until a bridge becomes available in the PI Hub. Likewise, after a truck drops its containers, if the hub-road bridge to which it is assigned is not available, there is a buffer area provided in the Truck zone, which is where the driver services are also located. The flow then is to the π-OutGate. On the train side, the train enters the π-hub via a gate if needed. The basic idea is to handle the train in a sequence of two operations repeated as much as needed to process the whole train. Two different sections in the hub represent the two operations. The number of railcars dealt with simultaneously and the number of handlers placed at the bridges allow scaling the hub according to the needs. The first section is the unloading section and the second section is the loading section. At the hub maximum size, a train will make two stops if the length of the section is the train length. Three stops if the length of the hub section is half train length, etc.

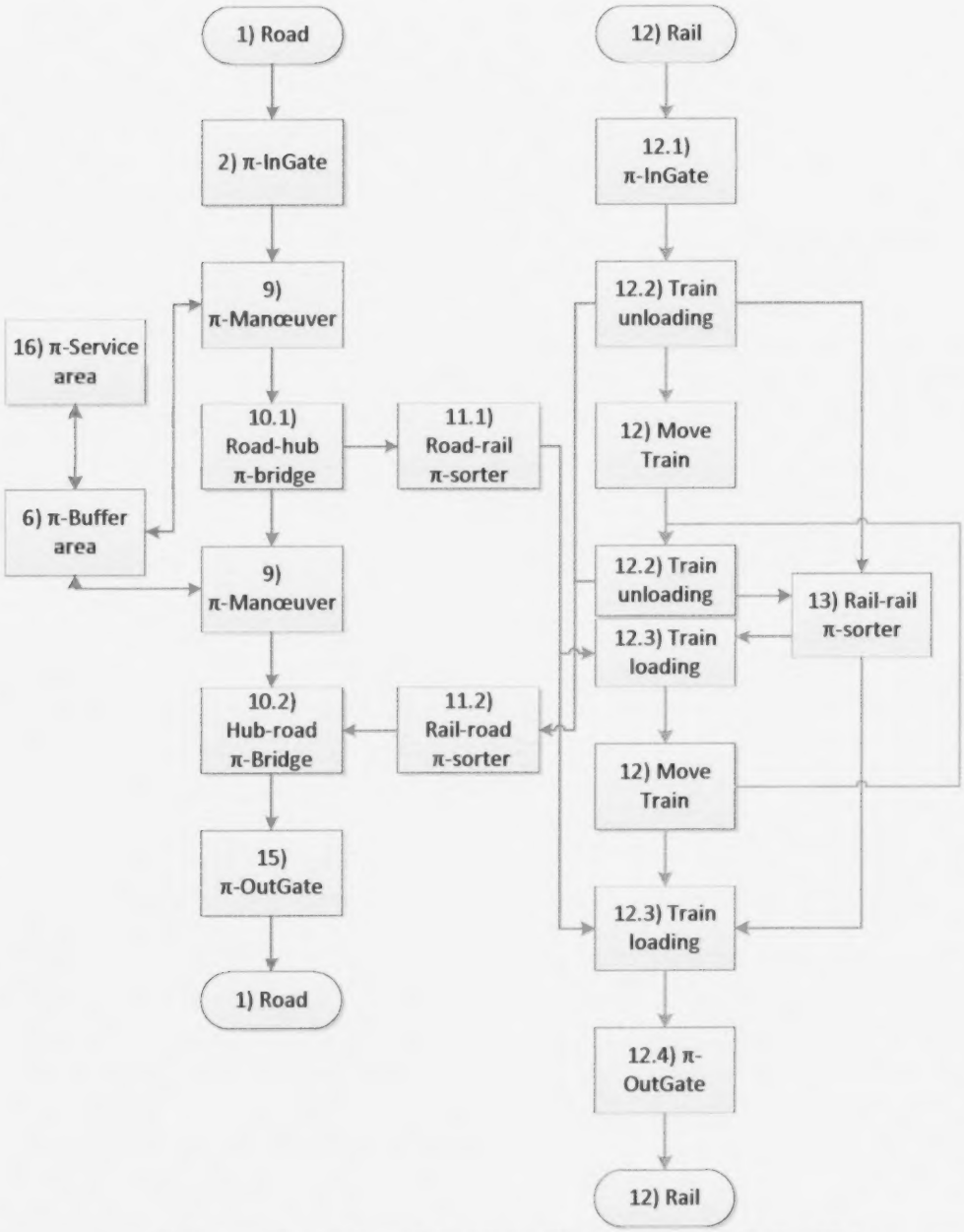

Figure 5: Illustration of the Major Flows in a Road-Rail π-Hub

In Figure 6 we present our functional design of a π-hub that implements the flow diagram.

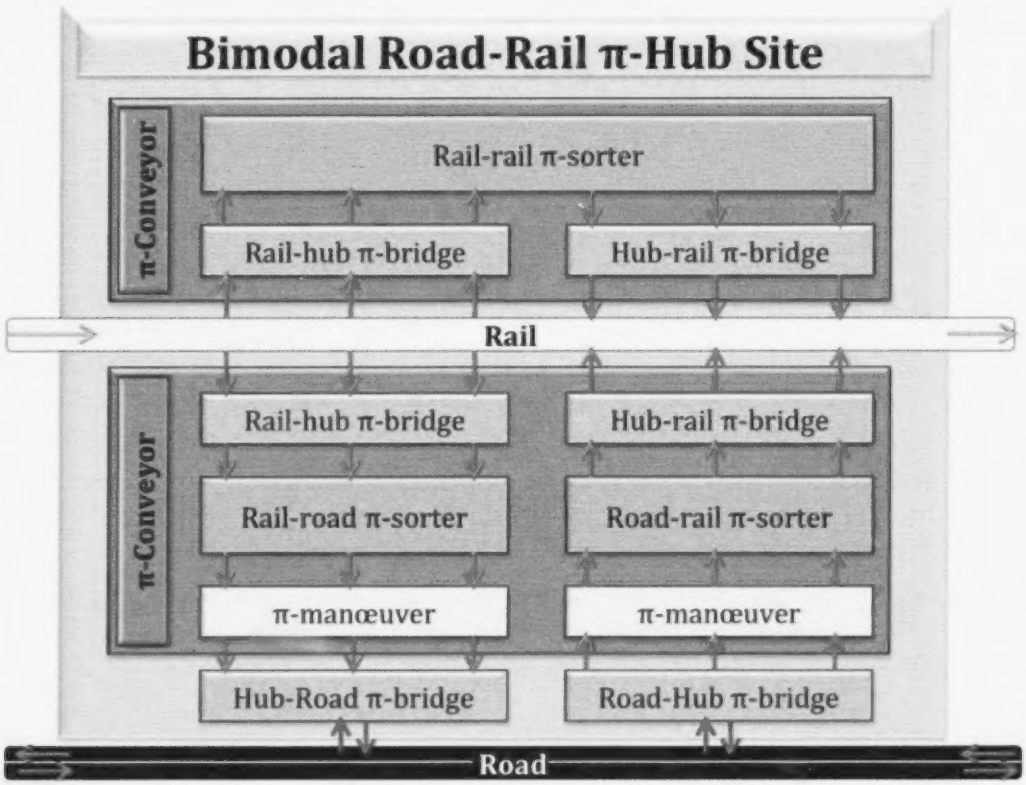

Figure 6: Proposed Functional Design of the Road-Rail π-Hub

What is really important to understand about this design is the following. The railcars are processed in four times:

1. unloading process,
2. train moves one-section forward, railcars to 2nd section of the π-hub and new railcars in the 1st section of the π-hub,
3. loading process of previously unloaded railcars and
4. train moves forward to either proceed as (2) above or to exit the π-hub.

This design ensure the scalability of the hub according to the amount of traffic. The block layout is shown below in Figure 7.

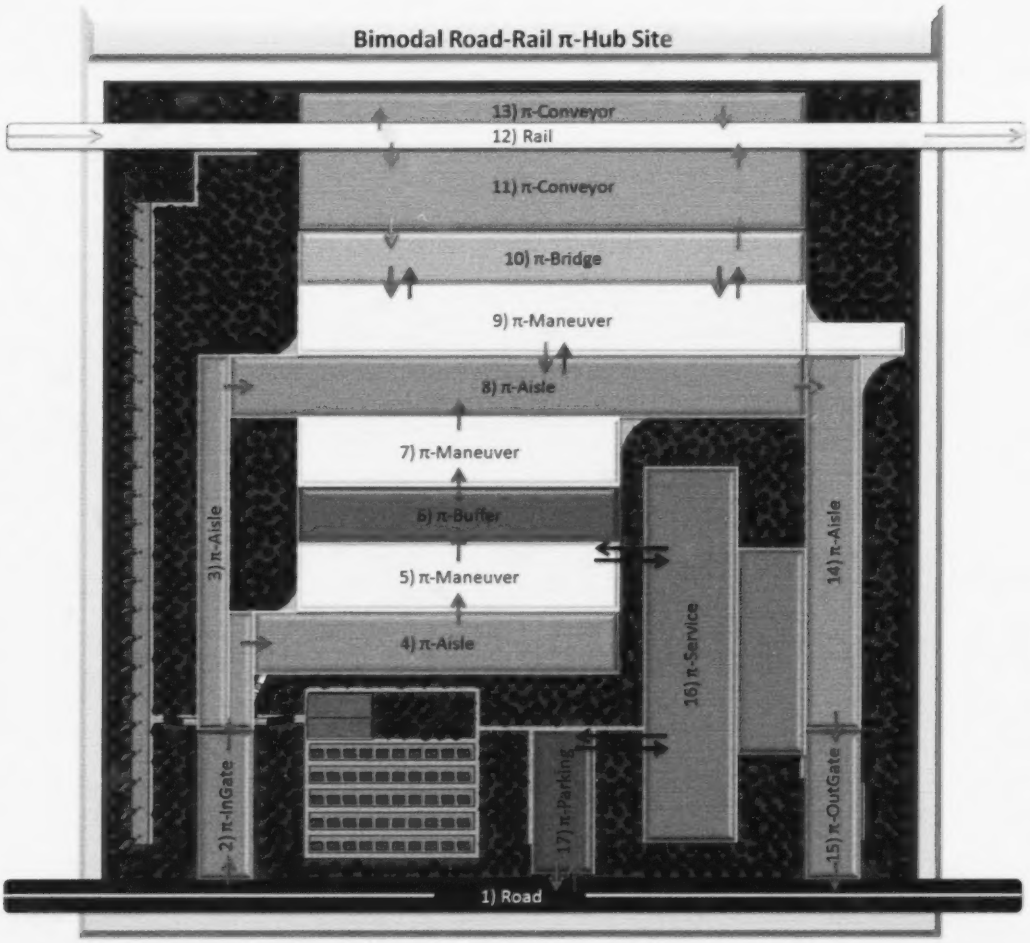

Figure 7: Block Layout for the Proposed Functional Design.

To ensure the completeness of our description of the functional design, we present a very detailed overview of the design in the Appendix.

3.3 Design Process

The proposed functional design can be implemented in many ways and with various technologies: e.g. stackers, robots or conveyors. At this stage, we explore through a stylized model the response time of a road-rail π-hub in relation with the number and the performances of the handling machines. The response of the π-hub is also very sensitive to another parameter: the number of containers to unload and load on each train. For instance, a railcar can carry a 12m π-container and a 6 m π-container. In this case fully unloading the railcar requires 2 operations. Alternatively if the railcar can also carry 15 π-

containers of 1.2m and this requires 15 operations. This is 7.5 times more effort than the previous case to unload a single railcar. On top of that, the percentage of the train's π-containers that have to be loaded and unloaded at each hub may also change. The first design questions are therefore: how many railcars could be processed simultaneously in the π-hub? Corollary, how many train stops are required? How many π-containers could be processed in parallel per railcar? To deal with these questions, a model of the demand (number and type of containers) is required.

At this exploration stage, only extreme cases will be taken into account to define the working domain, characterized by the time the train stops at the hub. In a second stage a more sophisticated design process would use analytical queuing models to determine the sizes of sorters, buffer and so on. Such models would be an improvement over the design ratios because the relationship between flow and capacity is non-linear.

3.3.1 Model Assumptions

We make a few simplifying assumptions:

1. Trains arrive on a scheduled basis and spaced in time to avoid any conflict between them.
2. As we are seeking for capacity limits we assume that a train is full at the entrance of the hub as well as at the exit.
3. The railcar offers 18m of length that can be use by any combination of containers within the defined set (according to this a full railcar carries between 2 and 15 π-containers).
4. A train is composed of N railcars
5. A train is processed in each section of the π-hub by n railcars.
6. Trucks operations are slave processes and trains operations are the master process.
7. The tack-time tt to handle a π-container (load or unload) is considered as a deterministic value.
8. The time to move the train the distance of a block of n railcars or a section in the hub is tm
9. The number M of total handler machines is a design parameter.
10. There is a probability p of unload /loading container at the π-hub.
11. There is a share between the lengths of the PI containers on a train per type and s_i represents the fraction of length used by π-containers of type i with $i \in S$ and we have: $\sum_{i \in S} s_i = 1$ in the case of full train load.

As mentioned previously, two KPIs would likely be quoted to potential customers of the PI rail-raod hub point:

1. The process time, encompassing the time the train will stay in the hub for unloading and loading of containers T.
2. The capacity of the hub per day in tons or number of π-containers.

3.3.2 Model

The objective of our model is to determine the time spent by the train in the hub according to the probability p of unloading/loading the π containers and the split between containers' lengths $\{l_i\}$. In this model, we set the useful length L of the train.

Thus, the expectation of number of loading or unloading operations H to be performed at the hub is computed by the following formula.

$$H = L \cdot p \cdot \sum_{i \in S} \frac{s_i}{l_i}$$

The time spent in the hub is the addition of the handling times at each step of the process and a traveling time of the train as it has to move to put a new block of railcars in front the handling machines for unloading and loading. In terms of handling time if we have more handlers (equally split between the unloading and loading operations) than handlings to perform we use the tt time as the minimum time. When the process start we can only perform unloading, so we need one more step in the whole process to finish it. Thus, the expected process time spent by the train in the hub during the process time is:

$$T = \left(Max\left(\left\lceil \frac{H}{M/2} \right\rceil, \left\lceil \frac{N}{n} \right\rceil\right) + 1\right) \cdot tt + \left\lceil \frac{N}{n} \right\rceil \cdot tm$$

3.3.3 Examples

We illustrate the above model with an example using the following data:

- Train arrives at the hub and requires that 30% of its containers to be unloaded and reloaded $p = 0.3$
- The train length is equally split between the set of containers $s_i = \frac{1}{card(S)}$
- The train is composed of 30 railcars, N=30, with a total useful length L=540m.
- Each of the two sections of the hub is 5 railcars long, n=5.
- The number of handling machines is M=10, 5 in parallel for unloading π containers from railcar and 5 in parallel for loading π containers on railcar. If a machine is required on each side, then multiply M by two.
- The cycle time per handling machine is 1 minute and time to move train from a position to the next is 3 minute.

According to these values, the number of π-containers to be moved is H=54 and the time spent is T= 30'30". If we have to unload a train full of smallest containers p=1 and $s_{1..2}$=1, it requires H=450 loading or unloading and it takes 2 hours and 3'. Stackers could perform this like in maritime containers' terminals.

If we change the number of handling machines to allow to move large containers with several handling machines together and smallest containers by one machine. We can install 5 railcars * 15 smallest container/railcar = 75 handling machines per section of the

terminal, M=150. In this case the T=25 minutes, whatever p and s_i values. It indicates that whatever the distribution of π-containers and number of π-containers to be handled, the time spent to process the train remains the same. This time would change only with the number of railcars.

It is possible to use this model to build an experimentation plan according to n and M that are closely related to investments. Figure 8 represents part of this experimentation plan. This choice of values represents a lower bound and upper bound of T according to investments in landscape and handling machines.

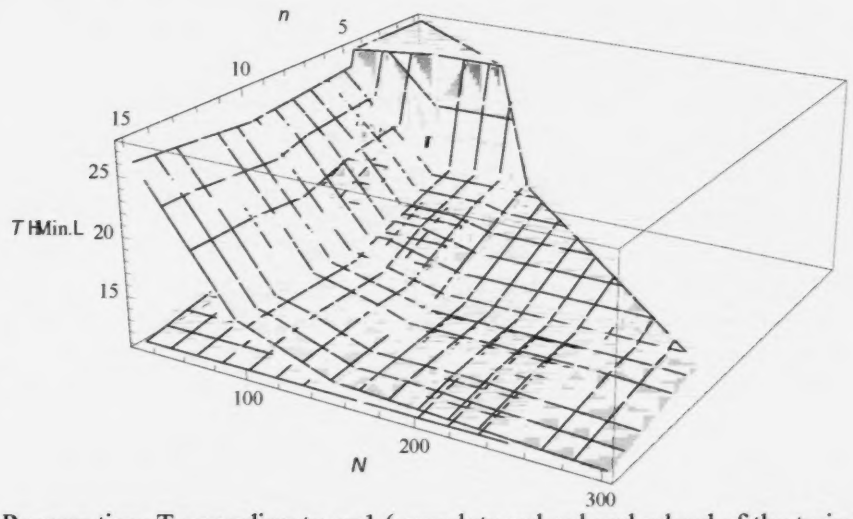

Figure 8: Process time T according to p=1 (complete unload and reload of the train in the hub) where the higher surface represents T according to $s_{1.2}$=1 (highest amount of handling) and the lower surface according to s_{12}=1 (smallest amount of handling)

The following layout is based on the last case with 150 small handling machines acting together to unload or load all containers on all railcars in the section of the hub in parallel.

3.4 Final Layout

For this section, we used the following data when determining our final layout:

- Arrival of trains are scheduled within a day with 3 assumptions of 10, 20 and 30 trains of 30 railcars, according to a 7-days-a-week schedule, it represents respectively:
  - [1,050; 2,100; 3,150] trucks/week (12m trailer) if p=1/3 of unloaded/loaded containers. With a 50% modal split to the road and 50% to another train it gives [525; 1,050; 1,575] fully loaded trailers to the road for example.
  - Average: [3.12; 6.25; 9.37] trucks/hour
- In hub Processing Time:

- Loading or unloading: 1 minute
- Moving train: 3 minutes
- There are four rows of conveyors on each side of the rail in the hub.

Using the overall design process introduced in the π-transit paper of this series [9], we sized the facility's capacity as follows:

- Number of InGates: 4 (2 normal-security and 2 high-security)
- Number of Buffer Spots for Truck-Trailers: 24
- Number of OutGates: 4 (2 normal-security and 2 high-security)

We now present our final layout from multiple perspectives. First is an overhead view of our final road-rail π-hub layout in Figure 9. It provides a sense of the facility from the front. Note the solar panel field on the left-hand-side of the site for environmental and energy production considerations. Next a 3D-view from the side in Figure 10, which not only illustrates the switch bays better, but also the wind turbines, which combined with the solar panel field, provide the energy requirements to the π-hub. Figures 11 and 12 put emphasis on the rail operations of the π-hub.

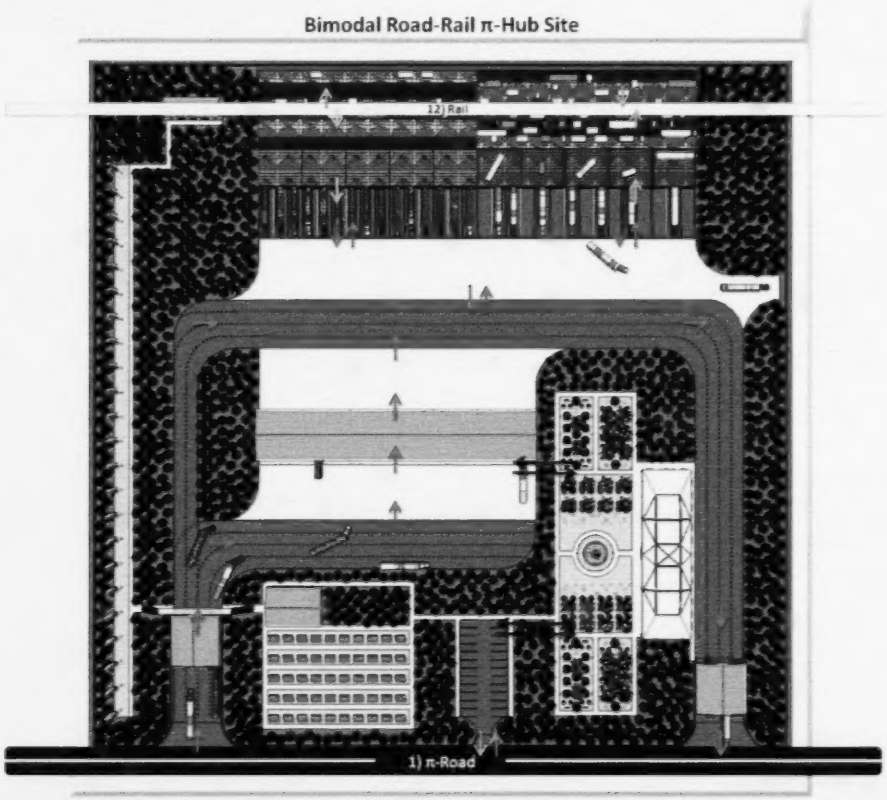

Figure 9: Final Layout of Proposed Design (Overhead View)

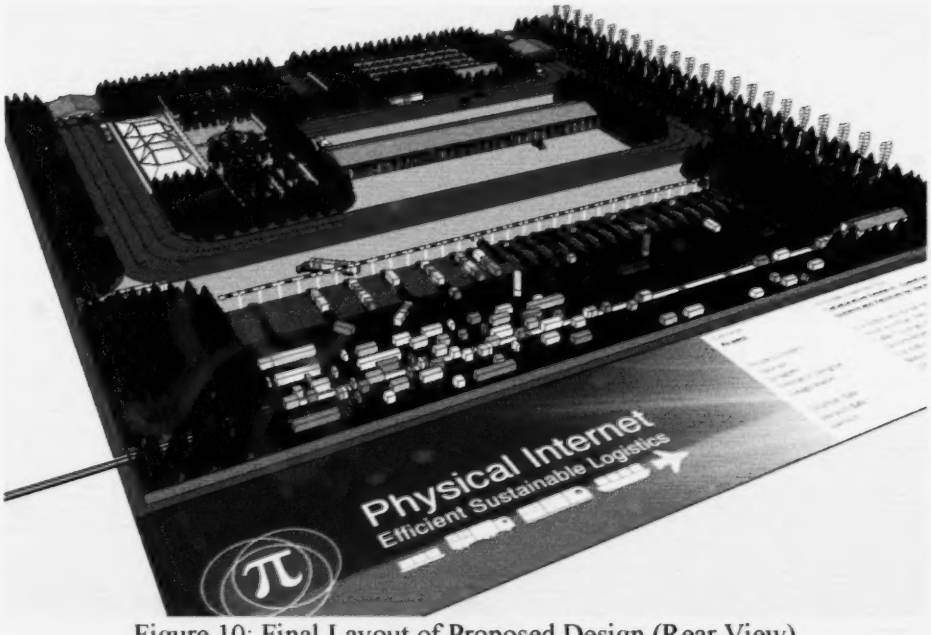

Figure 10: Final Layout of Proposed Design (Rear View)

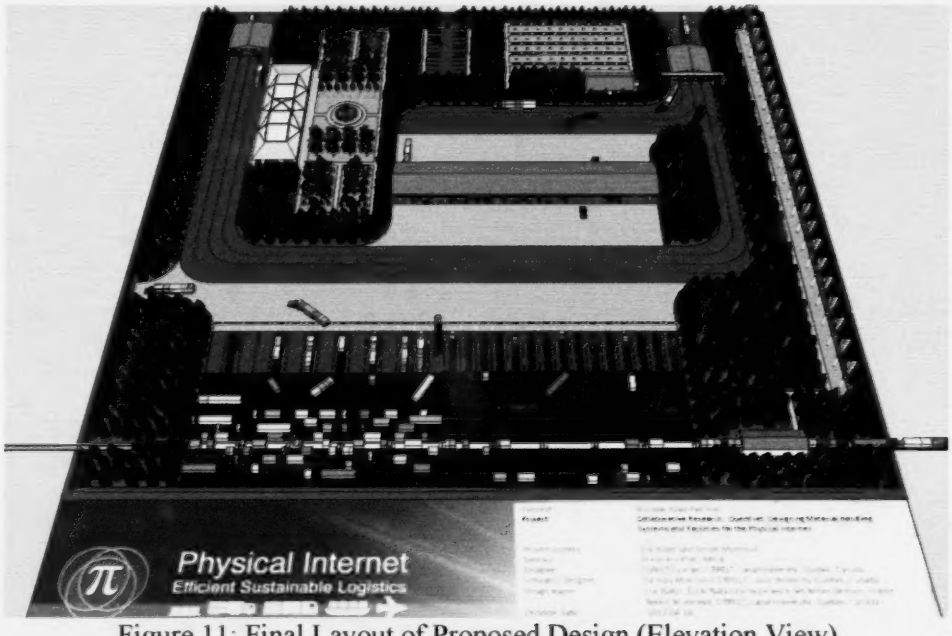

Figure 11: Final Layout of Proposed Design (Elevation View)

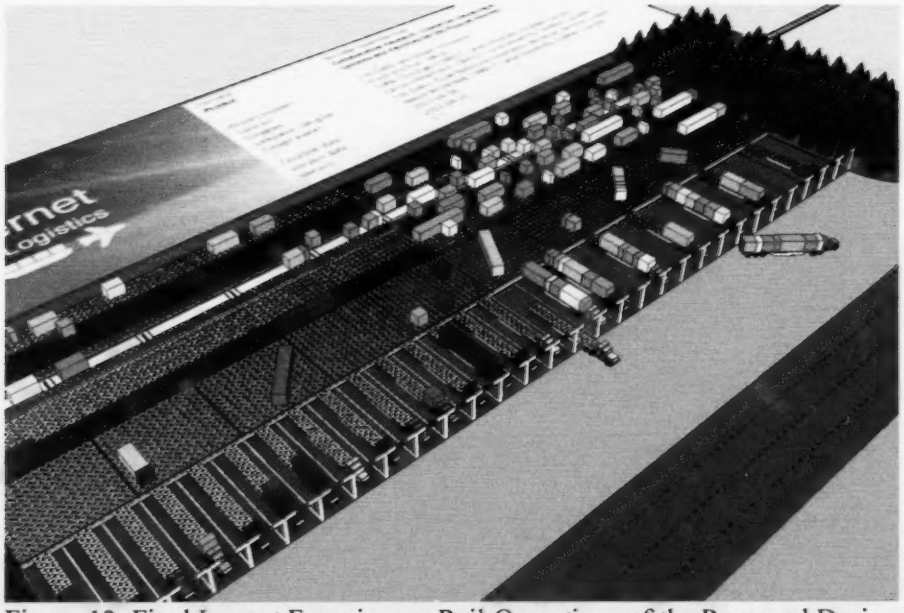

Figure 12: Final Layout Focusing on Rail Operations of the Proposed Design

Table 1. Key Performance Indices for the Proposed Design

KPI for 20 trains of 30 railcars per day, 7 days a week, p=1/3	**Value**
Customer	
Processing Time (Train)	25 minutes
Arrival of trucks per hour (Truck)	6.25
Average trains in connections	4
Maximum connecting time between road and rail	2h24 min.
Maximum connecting time between trains	4h48 min.
Operator	
Area of road-rail hub itself (without roads)	12,000 m^2
Number of railcars processed in parallel (load & unload)	10
Number of rows of π conveyors from road to train or vice versa	4
Number of rows of π conveyors from a train to another one	4
Number of containers processed in parallel per railcar	15
Number of road gates (In)	4
Number of road gates (Out)	4
Number of bridges Bays	24

3.5 KPIs of the Facility

We provide in Table 1 the values of the KPIs for this conceptual design allows the reader to get a sense for how well the facility is operating.

Table 2. Sensitivity Analysis of Proposed Design Performance

Railcar	Value	Unit
#/train	30	#
Total length	19,8	M
Useful length	18	M
Useful surface	43,2	M²
Useful volume	103,68	M³
Useful weight	60	T

Train per day	Equivalent railcars per day	Total length	Useful length	Volume M³	Weight	Probability of π-container length per train								Handling					
														Train moves	Handling	#railcars n			
														00:03:00	00:01:00	5			
						Width	2,4												
						Height	2,4												
						Length													
						1,2	2,4	3,6	4,8	6	12			Probability of handling	Unloading operations number	Handlers #	75		Train process time
1	30	624	540	3 110	1 800	17%	17%	17%	17%	17%	17%			30%	54				00:25:00
10	300	5 970	5 400	31 104	18 000	17%	17%	17%	17%	17%	17%			30%	536				04:10:00
20	600	11 910	10 800	62 208	36 000	17%	17%	17%	17%	17%	17%			30%	1 073				08:20:00
30	900	17 850	16 200	93 312	54 000	17%	17%	17%	17%	17%	17%			30%	1 609				12:30:00
1	30	624	540	3 110	1 800	17%	17%	17%	17%	17%	17%			100%	179				00:25:00
10	300	5 970	5 400	31 104	18 000	17%	17%	17%	17%	17%	17%			100%	1 788				04:10:00
20	600	11 910	10 800	62 208	36 000	17%	17%	17%	17%	17%	17%			100%	3 575				08:20:00
30	900	17 850	16 200	93 312	54 000	17%	17%	17%	17%	17%	17%			100%	5 363				12:30:00
1	30	624	540	3 110	1 800	100%	0%	0%	0%	0%	0%			100%	450				00:25:00
10	300	5 970	5 400	31 104	18 000	100%	0%	0%	0%	0%	0%			100%	4 500				04:10:00
20	600	11 910	10 800	62 208	36 000	100%	0%	0%	0%	0%	0%			100%	9 000				08:20:00
30	900	17 850	16 200	93 312	54 000	100%	0%	0%	0%	0%	0%			100%	13 500				12:30:00
1	30	624	540	3 110	1 800	0%	0%	0%	0%	0%	100%			100%	45				00:25:00
10	300	5 970	5 400	31 104	18 000	0%	0%	0%	0%	0%	100%			100%	450				04:10:00
20	600	11 910	10 800	62 208	36 000	0%	0%	0%	0%	0%	100%			100%	900				08:20:00
30	900	17 850	16 200	93 312	54 000	0%	0%	0%	0%	0%	100%			100%	1 350				12:30:00

Table 2 indicates how the design reacts to different hypothesis in term of percentage of containers unloaded from a train and distribution of containers sizes. As one can see this design is robust and ensure a constant train processing time that set the pace for the hub activities. Table 2 also shows that the design can cope with up to 30 trains per day. This represents already a huge amount of freight and typically above 2,000 π-containers handled per day.

As can be seen from Tables 1 and 2, the design of the hub is compact with 12,000 m^2 , especially when compared with a typical marshaling yard like Le Bourget near Paris with 216,000 m^2 of railroads with less functionalities (the road-to-train connection is not included here) but with the ability to deal with up to 100 trains per day compared to 30 with the hub's design.

4 Conclusions and Future Research

As stated at the outset, the goal of this chapter was not to produce the ideal design of a road-rail π-hub. Rather, our primary goal was to produce a functional design that performed at an acceptable level in terms of user key performance indicators (KPIs) and to explore its robustness with various flows. This design, only handling a subset of π-containers, already shows a possible improvement by an order of magnitude by sorting containers instead of railcars as marshaling yards do.

To illustrate our subject, we proposed an instantiation of the design for a specific configuration. The reader must be really aware that many others designs are possible. For example, there could be a configuration where the π-containers do not have to be turned by 90 degrees in the maneuvering zone. Or yet, there could be configurations capable of dealing with multiple trains concurrently. A German research program, called CaRL®-Seagate and focusing notably on container shipyards, has investigated hubs somewhat similar in intent. It generated a specific hub design [15] and developed technologies for horizontal handling of a set of containers.

The proposed design only provides approximate numbers and no optimization of needed resources. A comprehensive discrete-event simulation model is now required to measure accurately the foreseen performance and adjust resources in the sizing of the components.

In this process, it will be particularly helpful to have discussions with companies able to supply the technologies embedded in the hub in order to further validate, and amend as necessary, the hypotheses made here, especially the handling times, conveyor speeds, sorting algorithms, just to mention the more important ones.

Acknowledgements

This work was supported in part by the PREDIT research program in France, the Canada Research Chair in Enterprise Engineering and the NSERC Discovery Grant program in Canada. Any opinions, findings, and conclusions or recommendations expressed in this

material are those of the authors and do not necessarily reflect the views of the above programs. The authors also thank research students Marie-Anne Côté, Driss Hakimi, Christelle Montreuil and Zachary Montreuil for their help with hub sketching and figure production, and Professor Russell D. Meller for setting up the model of work presentation used in the three-paper series.

Appendix

The functional design presented in the core of this chapter is used here to describe in detail the PI road-rail hub. Please refer back to Figure 2. Several routings are possible depending on the entry and exit modes : road entry and rail exit, rail entry and road exit, and rail entry and exit. The road centric flows are here described first. Then the rail centric flows are described, both for getting into a subsequent train or existing by the road. Even though described sequentially, all these operations occur concurrently, meeting at the core of the PI hub.

1. Road to train or from train centric flows
   a. A truck, with a flat bed or pulling a trailer, presents itself at the PI Road-In Gate, carrying or not some PI containers (figure). It comes from another node of the Physical Internet hub network or yet from a local collection and/or delivery route.

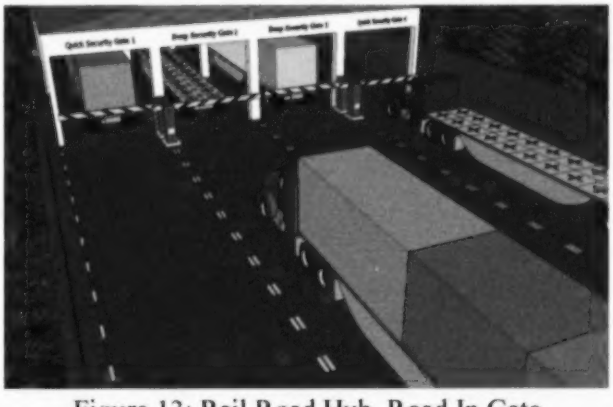

Figure 13: Rail Road Hub, Road In Gate

   The role of the PI Road-In Gate is to insure that the truck, the trailer when pertinent, its current and assigned PI containers are registered and expected in the planned time window. This verification is necessary so as to avoid bottlenecks in the PI hub.

   b. Before letting a truck into the hub, the PI Road-In Gate proceeds with a security check. This control can be performed at different levels of security checking depending on the PI hub location, the status of the

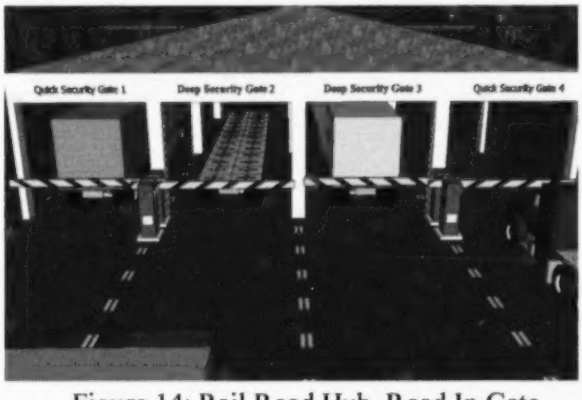

Figure 14: Rail Road Hub, Road In Gate

shipper, transporter and receiver, and stochastic control processes (figure 2). At the simplest level, for example with PI containers with non-dangerous contents transported between two sites of the same company, both being PI certified and in the same country, the control is to be minimal, limited to weight checking, coding identification, temperature, validation of electronic seals, and so on. At the other extreme, if for example one of the inbound PI containers is to be exported, from an uncertified shipper, and/or to an uncertified recipient, then the PI containers will be thoroughly scanned so as to allow the PI hub operator to verify the content before letting these PI containers in the PI hub and into the Physical Internet, and to allow competent authorities to intervene if necessary for adjusting rights and taxes or for performing a more thorough inspection. In all cases, the passage through the PI Road-In Gate allows to associate a driver's license to an actual driver, an operator and a truck, and to associate the truck with a set of PI containers and a trailer when pertinent.

c. Once the truck and its load are identified and the security of its contents is validated, a destination within the PI hub is assigned to the truck. It may be directed towards an inbound or outbound PI Bridge dock within the road-rail PI hub if it is available and the lead

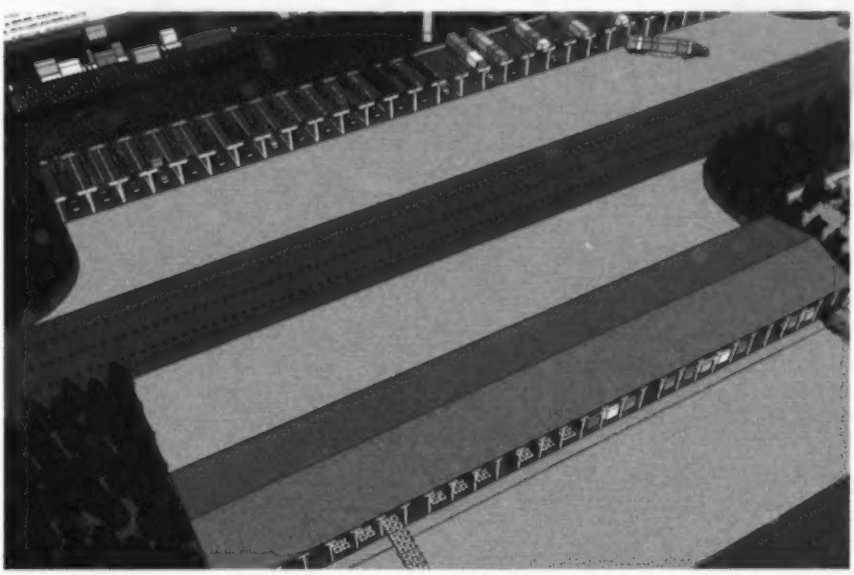

Figure 15 – Buffer case

time is compatible, the trailer or the case, or it may be directed towards a bay of a PI Buffer (figure 3). In all cases, this necessities that the PI hub management system be kept informed of the past moves of the set of PI containers, with a regular update of the estimated time of arrival of PI containers known to be incoming.

Exploiting this information, the PI hub management system may thus confirm the allowed arrival windows and dynamically assign the truck either to a bay in a PI Buffer or to a dock in the inbound or outbound PI Bridge. Many cases are possible at this stage.

i. As requested when passing the PI Road-In Gate, the truck and its trailer (when pertinent) are routed directly towards an inbound PI Bridge dock of the PI hub for PI container unloading. The truck is thus directed without delay to the assigned dock. It is a synchronous operating mode. This avoids any unnecessary operation, yet it cannot be generalized to the entirety of a set of flows subject to stochastic occurrences.
ii. The truck and its loaded bed or trailer are channelled to a PI Buffer bay. Two operating modes are here possible. First, they wait for an inbound PI Bridge dock to get available and are directed towards it when their assignment to it is confirmed. Second, the tractor lets its trailer in the PI Buffer bay and is directed to another bay so as to pick up another trailer. In this second mode, when the time is right, a manoeuvring tractor is charged to move the trailer to an inbound or outbound PI Bridge dock of the road-rail PI hub. This is an asynchronous operating mode.
iii. The truck, with its empty bed or trailer, is directed towards a PI Buffer bay or to an outbound PI Bridge dock of the PI hub so as to respectively be waiting or be loaded with PI container(s). This is also an asynchronous operating mode.

d. An inbound PI Bridge dock on the right side of the PI hub is communicated to the driver of truck loaded with PI container(s). The proposed PI hub layout operates with a rear docking, yet it is easy to imagine alternative angled docking or side docking. The latter alternative avoids turning PI containers within the PI

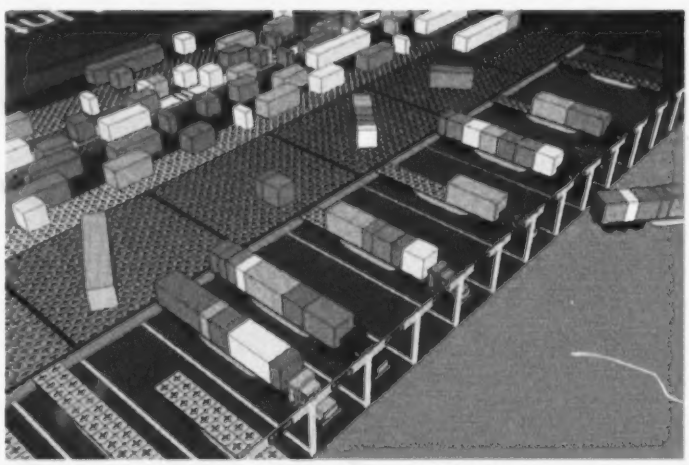

Figure 16 : inbound PI Bridge

hub yet restricts the docking capacity in terms of number of trailers concurrently docked for a given docking length. Subsequent more elaborate studies will be necessary to investigate the impact of the alternative docking ways. At an inbound PI Bridge dock, all PI containers having to get into a train are unloaded and placed on a grid of four-direction conveying modules (figure 4). A conveying module here has a functional length of 1,2m and a 2,4m width. These are the minimal dimensions of PI containers dealt with in the proposed PI hub. A 6m-long PI container occupies five conveying modules that are capable of moving it in a coordinated way. The four directions the modules can move are towards or away from the railway, and laterally forward or backward parallel to the railway. Through such movements, the PI containers are gradually brought towards their assigned location on the PI Conveyor, ready to get into their assigned railcar at the right time, in the right order and in the right position. This entails managing a stack of time-phased positioning requests, avoiding PI container bumping into each others and creating deadlocks. A system has to optimize the allocation of inbound PI Bridge docks to trucks so as to minimize their movement through the PI hub and to insure that their PI containers reach their position beside their assigned railcar location in timely and orderly fashion with minimal overall PI container movement and congestion. A truck/trailer may carry PI containers that have different destinations, thus potentially having to board on different railcars, potentially on different trains. Technologically, the conveying modules can be of similar nature as the recently introduced flexconveyors by GEBHARDT in Germany, yet deployed at a bigger mass scale. The decentralized conveyor grid management system proposed for flexconveyors [14] could potentially be upgraded so as to be exploited here, with new capabilities to support collaborative actions such as when sets of conveying modules move a long PI container.

e. The PI containers offloaded from trucks or trailers are thus progressively moved towards their assigned PI Conveyor (figure 18) so as to be loaded in the right position on the right incoming railcar.

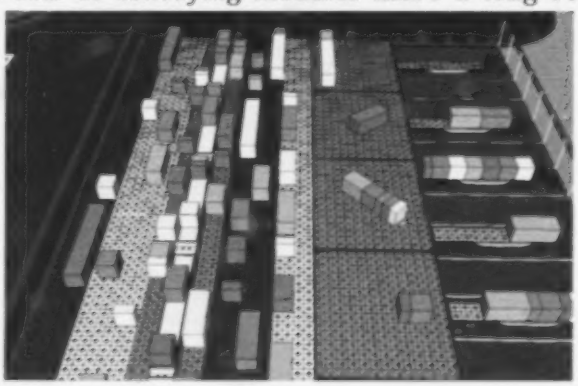

Figure 17: PI conveyors

f. Once the truck, and its trailer when pertinent, have offloaded their PI container(s), several avenues are possible.
   i. In the ideal situation, the truck and its trailer are assigned without delay to an outbound PI Bridge dock located on the left side of the PI hub, and allocated a set of rail-incoming PI container(s). These are loaded on the carrier as soon as they reach it. When all allocated PI containers are loaded, the truck moves towards the PI Road-Out Gate.
   ii. Alternatively, the truck can deposit its trailer in a PI Buffer bay and take a loaded trailer ready for departure.

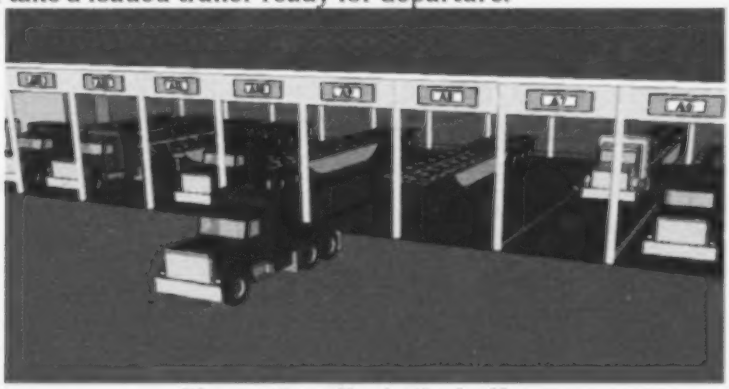

Figure 18: trailer in the buffer

   iii. Also, the truck may have to wait for a load of PI containers that will arrive later on a subsequent train. In such a case, the truck is directed to wait in a PI Buffer bay, corresponding to case1.f.i.
   iv. Finally, the truck and its trailer may opt to head towards the PI Road-Out Gate, aiming to leave the PI hub unloaded, for example to get a load through a local tour of shippers.

g. Whatever the option in 1.f, when the truck decides to leave the PI hub, loaded or unloaded, it moves without delay to the PI Road-Out Gate where the driver, the truck, the trailer (when pertinent), the PI containers (again when pertinent) and the destination are identified, validated and published, figure 19

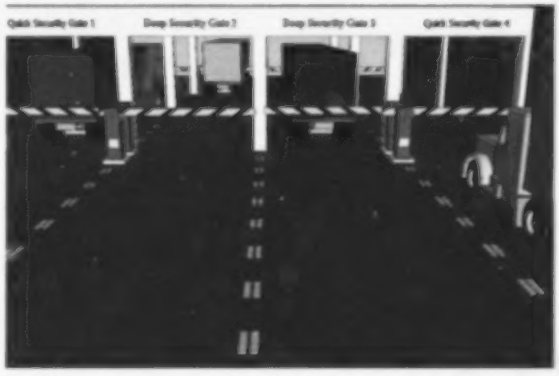

Figure 19: Road-rail Hub, road Out-Gate

In parallel to the road-based operations, rail-based operations are performed.

2. Train centric flows

a. A train arrives at the PI Rail-In Gate. At the previous hub, this train has been maximally loaded within its capacity, leaving remaining PI containers to be either reported to a next train or transferred to road travel. As depicted in figure 7, the PI Rail-In Gate has two characteristic elements. First is a side forking relative to the main railway. Second is a security portico. In cases requiring high security, such when passing a border, the portico may scan all PI containers and verify them relative to the train's manifest. Minimally, a sensor reading is performed so as to identify and to locate the train drivers, the train, the set of railcars, set of PI containers, validating their position within the train's railcars and aiming to avoid handling errors. It enables the validation of the unloading and loading plans to be realized. Any anomaly leads to a manual verification and validation so as to re-compute the plans and eventually modify their position. Once the elements of the train have been validated, the train is allowed to move its n first railcars into the hub, stopping at a precise location to align with the hub's unloading bridges.

Figure 20 : PI Road-rail Hub, Rail In-Gate

b. Once the train has stopped, pick-and-place type robots grab PI containers having to be unloaded at this PI hub, so as to perform the unloading operation. Such unloading operations can be performed in parallel on all railcars parked along the PI Conveyor. The parallelism is bounded in theory only by the number of available unloading robots on each side of each railcar and by the total number of PI containers to be offloaded from the parked railcars. In the proposed

design, adjacent PI containers are not offloaded concurrently for safety purposes, except if they are to be considered as a composite PI container by the PI hub: this bounds the number of concurrent offloading operations. The PI containers are offloaded towards the rear side of the PI hub when they have to be re-loaded on a subsequent train. They are offloaded towards the PI hub's front side when they have to be transferred to road travel. Along both sides, they are transferred on the grid of conveying modules described earlier. First the conveying modules convey the PI containers away from the railcar so as to allow the next wave of unloading operations to proceed.

c. The train moves forward so as to let the next n railcars enter the hub.

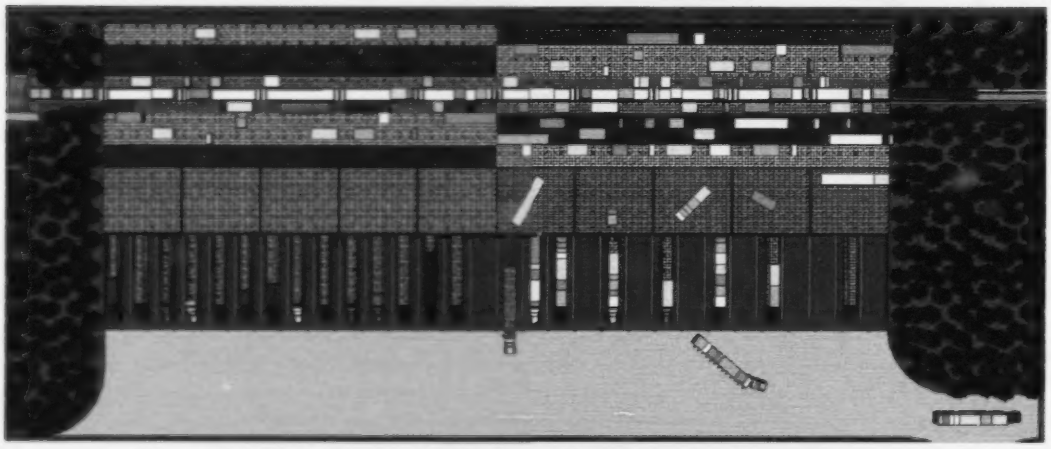

Figure 21: Train stopped with first railcars in unloading positions.

d. Three types of operations are performed concurrently.
   i. The unloading of PI containers from the new set of railcars on the PI Conveyor, according to the same process described in 2.b.

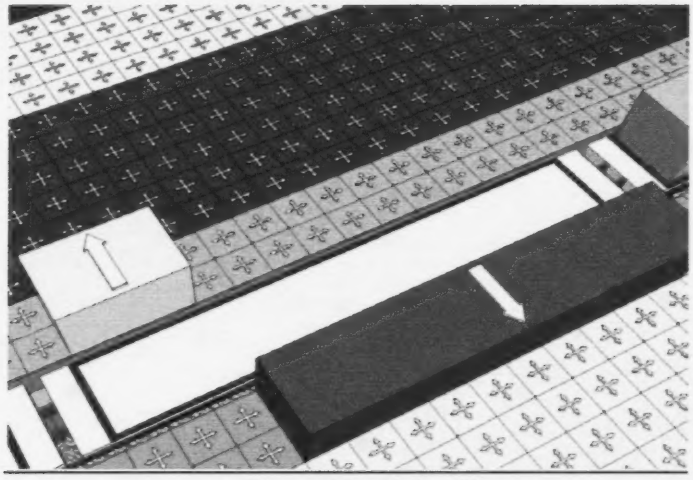

Figure 22 : Unloading

ii. Previously unloaded PI containers are moved within the conveying grid towards their assigned PI Bridge dock from road bound PI containers (step 1.f.i) and towards the train loading right zone on the rear side of the PI hub.

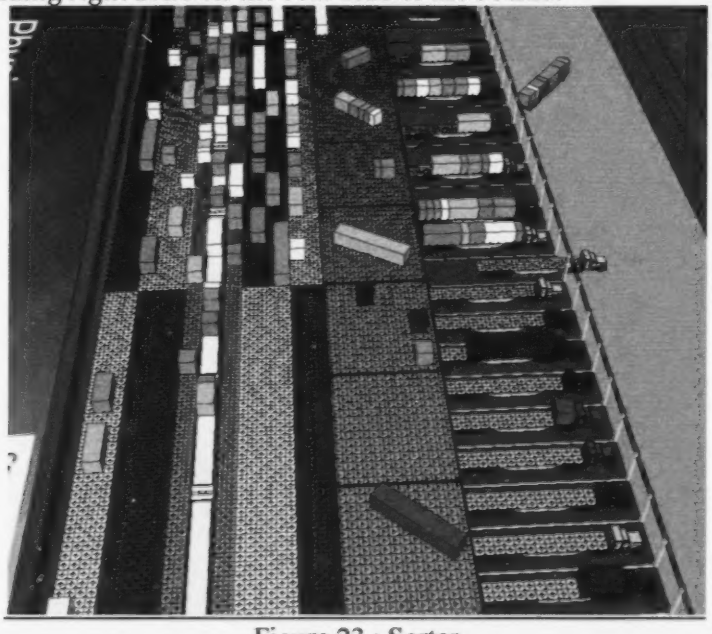

Figure 23 : Sorter

iii. The right front part of the PI hub receives the n railcars that have just been offloaded (step 2.b) prior to the train's move. These n railcars are now to be loaded from the rear side with

PI containers coming from previous trains, and from the front side with PI containers having been recently offloaded from trucks (step 1.d).

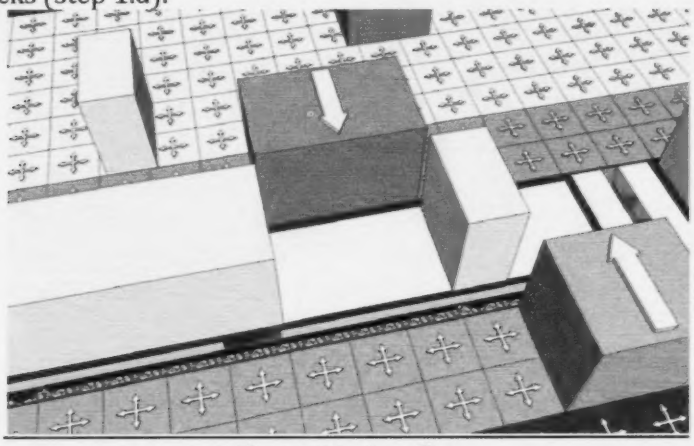

Figure 24 : Loading

e. Operations 2.b and 2.c are repeated the number of times necessary for treating the entire train.

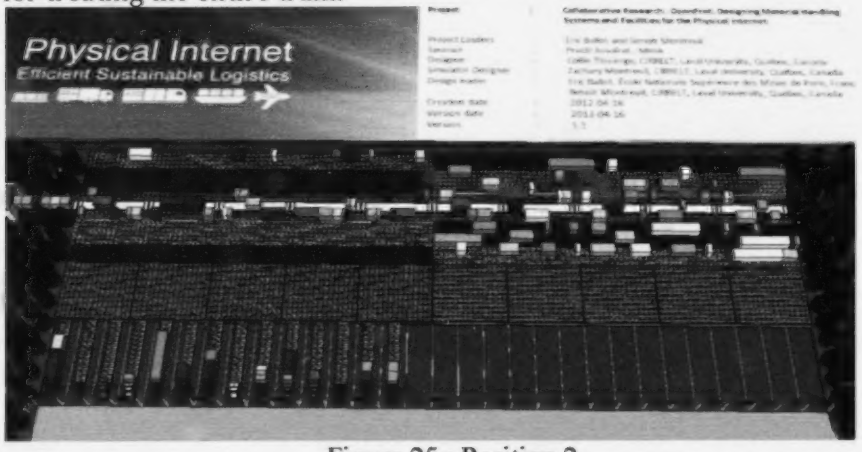

Figure 25 : Position 2

Figure 26 : Position 3

f. Finally comes a time when the last set of railcars has to be loaded (as in 2.c.iii) while there is no further unloading.

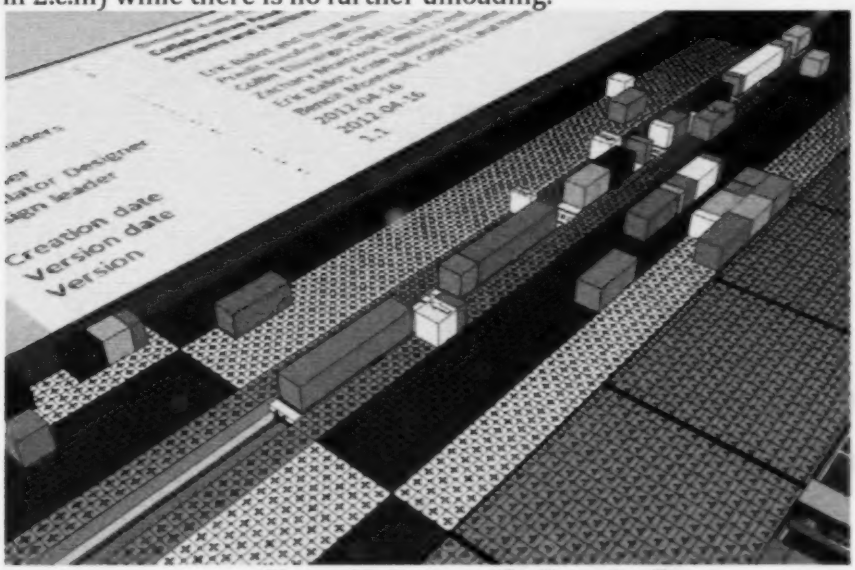

Figure 27: Last set of railcars loading

g. Some sets of railcars may pass in front of the loading/unloading PI Conveyor without stopping. Indeed, move optimization makes it pertinent to concentrate in the same or adjacent railcars PI containers having the same destination. Railcars with no PI container having to be offloaded or loaded may pass straight forward without stopping, saving energy and time.

h. Once all its railcars have been unloaded and re-loaded as prescribed, the train moves into the PI Rail-OutGate. First a final checking is performed. Once granted permission to leave, the train moves forward out of the PI hub onto the railway.
i. Between two trains, the conveying grid performs the moves necessary for emptying the unloading portion of the grid both a road and rail outbound sides, and for preparing the loading portion of the grid, dealing with arriving trucks and their PI containers having to depart on the next train. Thus, between trains, the conveying grid acts as high-density sorter, handling and storage system.

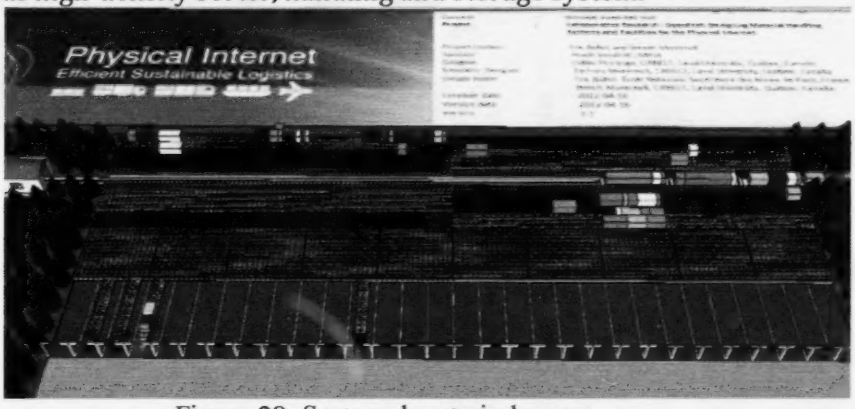

Figure 28: Sorter when train leaves

References

[1] Ballot, E., Glardon, R. and Montreuil, B., "OpenFret: Contribution to the Conceptualization and Implementation of a Road-Rail Hub for the Physical Internet," PREDIT, France, 1-126 (2010).

[2] Ballot, E., Montreuil, B. and Glardon, R., "Simulation of the Physical Internet in the Context of Fast-Moving Consumer Goods Sector in France," PREDIT, France (January 2011 – June 2012).

[3] Ballot, E., Montreuil, B., and Thivierge, C., "Functional Design of Physical Internet Facilities: A Road-Rail Hub," in *Progress in Material Handling Research: 2012*, Material Handling Institute, Charlotte, NC, pp-pp (2012).

[4] Kelton, W. D., Smith, J. S., Sturrock, D.T., *Simio and Simulation: Modeling, Analysis, Applications* (software version: 4.62.7799), McGraw Hill, (2012).

[5] Meller, R. D. and Ellis, K. P., "An Investigation into the Physical Internet: Establishing the Logistics System Gain Potential," in *Proc. of the International Conf. on Industrial Engineering and Systems Management*, Metz - France, 575-584 (2011).

[6] Meller, R. D. and Ellis, K.P., "Establishing the Logistics System Gain Potential of the Physical Internet," U.S. National Science Foundation and Physical Internet Thought Leaders (June 2010 – June 2012).

[7] Meller, R. D., Lin, Y.-H., and Ellis, K. P., "The Impact of Standardized Metric Physical Internet Containers on the Shipping Volume of Manufacturers," in *Proceedings of the 14th IFAC Symposium on Information Control Problems in Manufacturing*, Bucharest – Romania, pp-pp (2012).

[8] Meller, R. D. and Montreuil, B, "Designing Material Handling Systems and Facilities for the Physical Internet," Material Handling Industry of America (2010/07 –2012/06).

[9] Meller, R. D., Montreuil, B., Thivierge, C., and Montreuil, Z., "Functional Design of Physical Internet Facilities: A Road-Based Transit Center," in *Progress in Material Handling Research: 2012*, Material Handling Institute, Charlotte, NC, (2012).

[10] Montreuil, B., "The Physical Internet," Roundtable Discussion, 2010 International Material Handling Research Colloquium, Milwaukee (WI; USA), June (2010).

[11] Montreuil, B., "Toward a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge," *Logistics Research*, **3**(2-3), 71-87 (2011).

[12] Montreuil, B., Meller, R.D., and Ballot, E., "Towards a Physical Internet: The Impact on Logistics Facilities and Material Handling Systems Design and Innovation," in *Progress in Material Handling Research: 2010*, Material Handling Institute, Charlotte, NC, 305-327 (2010).

[13] Montreuil, B., Meller, R. D., Thivierge, C., and Montreuil, Z., "Functional Design of Physical Internet Facilities: A Distribution Hub," in *Progress in Material Handling Research: 2012*, Material Handling Institute, Charlotte, NC, (2012).

[14] Sarraj, R., Ballot, E., and Pan, S., "Potential of routing protocols for freight in open logistics networks: the case of FMCG in France". in *4th International Conference on Information Systems, Logistics and Supply Chain*. Québec, Canada, (2012).

[15] Gue, K.R. and Byung S.K., "Puzzle-Based Storage Systems", Naval Research Logistics 54 (5), 556-567, (2007).

[16] Innovative Seehafentechnologien II (ISETEC II), accessed on 2012/06/01 at http://www.bmwi.de/BMWi/Navigation/Service/publikationen,did=372034.html